'BRITISH FRIGATE GOES BACKWARDS'

FAILURE AND REPAIR OF A CONTROLLABLE-PITCH PROPELLER IN H.M.S. 'LINCOLN'

BY

LIEUTENANT R. W. TURNER, R.N.

The headlines 'British Frigate Goes Backwards', which appeared in the Hong Kong local Press, allowed for a certain amount of journalistic licence although containing an element of truth. In effect, it was the port propeller that went 'backwards', or, more precisely, the blades of the controllable-pitch propeller swung to astern pitch, and then only if a speed of 10 knots was exceeded. A more accurate account of the failure and repair of the Stone-Kamewa controllable-pitch propeller actuating gear will probably be of interest

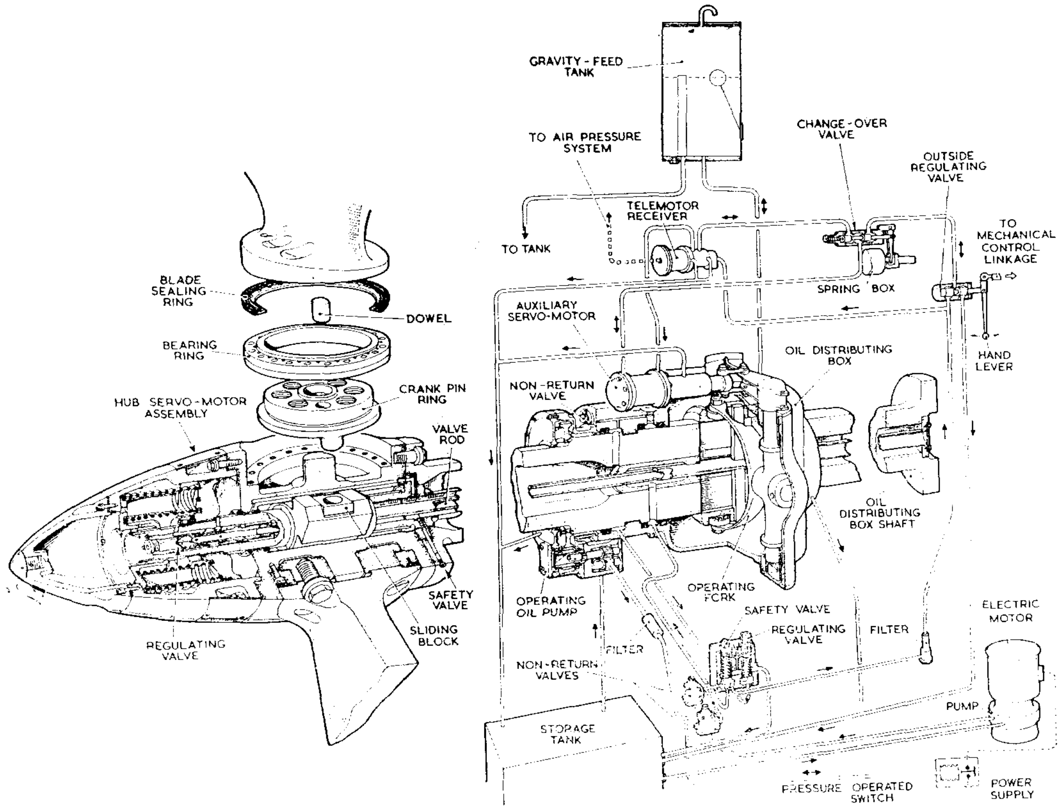

FIG. 1—STONE KAMEWA C.P.P. INSTALLATION

to readers. A detailed description of this installation is contained in Vol. 12, No. 2 of this *Journal* but a brief description now may be of help. The system is shown diagrammatically in FIG. 1.

The propeller hub is fitted with three normal, but removable, blades having circular roots which are each bolted to a crank pin ring in the hub. A spigot on this ring engages into a common sliding block, which is mechanically connected to a servo-piston in the propeller hub and also the operating valve liner, but permitting limited free movement of the valve pin, so that movement of the piston rotates the blades from maximum ahead pitch of 32 degrees to a maximum astern pitch of 20 degrees. Maximum efficiency of the ahead position is at $28\frac{1}{2}$ degrees, denoted as the 'design pitch'.

The control is normally from the Engine Control Room (ECR) by an air-operated telemotor system. The receiver, located on top of the oil distribution box in the plummer block space, controls a servo-motor which moves an operating arm and yoke inside the box. The yoke fits round a brass sliding ring on the propeller shaft. A steel key, fitted radially through the sliding ring, passes through a slot in the shaft so that both rotate with the latter. It is also attached to the inboard end of an operating valve rod or tube in the centre of the shaft. A bloctube system can also operate the servo-motor on the oil distribution box from a secondary position in the respective port or starboard engine room, and there is a local control hand lever fitted on each box. A five-degree alteration of pitch can be made by the trimming valves situated on the Bridge, which actuate on the ECR transmitters.

Two oil pumps, one electric and the other shaft-driven, supply oil at 300–350 lb/sq in. to the operating gear of each propeller through the oil distribution box. When normally under way, the electric pump is stopped and set automatically to cut-in if the oil pressure drops to 50 lb/sq in. It is normally run when the ship is manœuvring. This high-pressure oil is fed through ports in the oil distribution box into the bore of the actuating valve rod or tube, and thence to the servo unit in the propeller hub. This valve rod is 73 feet long, made up in seven sections, coupled together, and located in the centre of the propeller shaft by means of spaced wings on its external surface. A valve pin on the after end of this rod, joined to it by a bayonet connection, slides in the liner which is drilled with ports leading to the forward or after side of the servo unit piston. Eight springs acting on the after face of the piston ensure that the blades will rotate to the full-ahead position should there be a failure of oil pressure.

To set the blades astern, the servo motor moves the sliding ring, valve rod and valve pin aft, cracking open ports in the liner to allow H.P. oil to act on the forward face of the piston in the hub against the spring pressure. Transfer ports also open to allow the oil pressure on the back of the piston to be released into the propeller shaft bore round the valve rod and so to the oil distribution box. The box is maintained full of oil from a gravity tank situated on the boat deck to ensure an oil pressure on the blade seals at all times.

As the blades rotate through pressure on the piston, the ports are closed due to the connection between the sliding block and valve liner, but progressive movement of the valve rod will continue the piston and sliding block movement until the desired pitch is obtained. Ahead pitch is obtained by applying the oil pressure to the after face of the piston and so backing up the springs.

Of interest to the defect, the valve pin has a total axial movement of 0·310 inches in the liner and the sliding ring 10 inches movement on the shaft, being limited by the length of the slot.

The Failure

H.M.S. *Lincoln* was on passage from Singapore to Hong Kong and had been keeping station at 14 knots on H.M.S. *Triumph* for about three hours. The Officer of the Watch had set bridge trimmers to the full-ahead position with ECR C-P controls at design pitch, so avoiding going beyond design pitch, and found this position kept station well. *Triumph* ordered a reduction of speed to 13½ knots and by moving bridge trimmers to the midships or neutral position, with no alteration to the ECR controls, the ship continued in station.

The electric oil pump was running on the port shaft supplying oil at 300 lb/sq in. for C-P control, the shaft-driven pump having been disconnected at Singapore due to a hydraulic 'knock' in the discharge line subsequently found to be caused by a leak in the flexible suction line.

Approximately thirty minutes after reducing speed the ship veered violently to port and lost steerage way. It was seen from the bridge that the port propeller was going astern. No knowledge of this was known in the ECR except for undue vibration throughout the ship and that the port pitch indicator was at maximum ahead position, the starboard indicator still being at design pitch. Both shafts were turning at 123 r.p.m. and the C-P oil pressure steady at 300 lb/sq in. on both sides.

Both shafts were stopped, but further attempts to proceed resulted in the port blades swinging astern when a speed of 10 knots, or 100 r.p.m., was exceeded, but there was no further movement on the ECR pitch indicator. The C-P propeller control was tried from the secondary for'd engine position and then on local control on the oil distribution box, but it was found that the operating arm of the yoke was jammed in the full-ahead position. Unsuccessful attempts were made to move this operating arm aft, first by servo-motor control alone and then by backing up with chain blocks. The link pins between the operating arm and servo motor were disconnected to ensure correct operation of the latter. This was satisfactory, indicating that the sliding ring in the oil distribution box was seized or jammed on to the propeller shaft. The high-

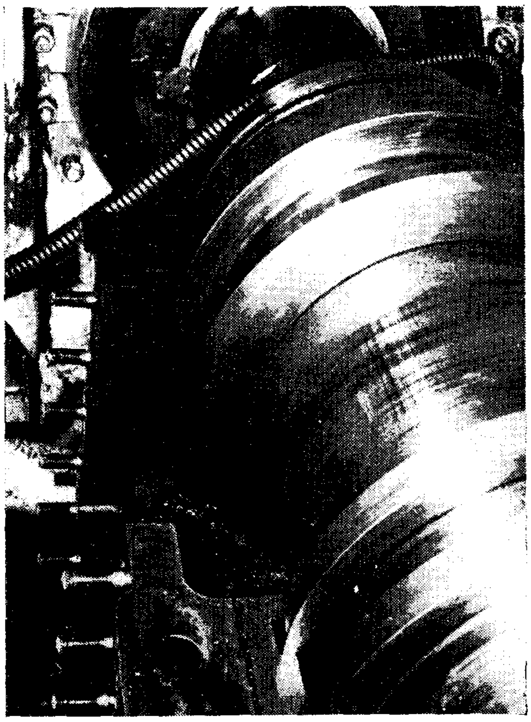

FIG. 2—SEIZED SLIDING RING

pressure oil was maintained at all times with the electric pump and no undue overheating of the oil distribution box was apparent.

The ship proceeded to Hong Kong at a speed of just under 10 knots. Revolutions on the port shaft were limited to 100 and on the starboard shaft to 110. Any excess of these revolutions caused the port propeller blades to swing astern. Continual watch was kept on temperatures of the oil distribution box and these gradually decreased from a maximum of 145 degrees F to 135 degrees F.

After the ship berthed at Hong Kong divers were sent down to note any oil leaks from the hub or propeller blade sealing rings. None was observed and it was noted that the port blades were set at 27½ degrees ahead pitch ,according to graduations on the hub.

The Repair

The first objective was to examine internally the oil distribution box. The gravity tank on the boat deck provides a head of oil through this box and so to the propeller hub and blade seals, preventing ingress of water into the hub. As no excessive oil leaks had been found by the divers, it was decided to drain down the oil system into the main C-P oil tanks and remove the front and back covers of the oil distribution box. The operating arm and yoke of the sliding sleeve were fitted to the front cover and on its removal it was seen that the sliding ring had been forced into the extreme forward position and had been scuffing against the oil distribution box casing adjacent to the forward bearing (FIG. 2). Brass particles were found in the bottom of the box. As the box swings freely on the shaft, a torque arm is bolted to the bottom which bears against an angle bracket welded to a hull frame to prevent the box rotating and putting undue strain on the pipe connections. Both the torque arm and the angle bar were found to be bent.

An endeavour was made to move the sliding ring aft on the shaft by levering against the box, but to no avail. The key between the sliding ring and valve rod pin was removed, but further attempts to move the ring with screw jacks were also unsuccessful. The key, when checked on a face plate, was bowed 0·064 in. indicating that the valve rod and pin had forced the sliding ring hard against the oil distribution box casing.

Not having freed the ring, the next step was to split the oil distribution box at its horizontal joint. The bottom half was supported on blocks and the top half lifted after all control and top gear had been removed. It was then seen that the forward, after and location bearings were partially wiped (FIG. 3) and whitemetal had apparently run from the forward bearing to bond the sliding ring on to the shaft. Further attempts were made to move the ring by jacking, but only $\frac{3}{16}$-inch movement could be obtained.

SPDS (Singapore) were contacted and a spare shaft section, with sliding, ring valve rod pins and liners were flown from Singapore, as it was

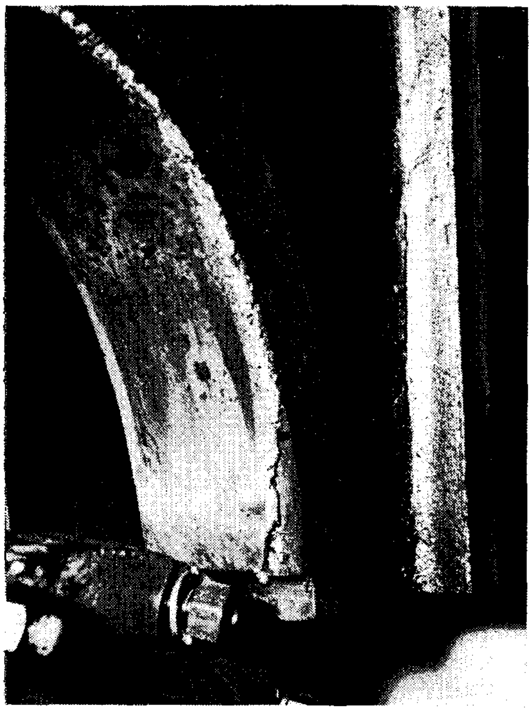

FIG. 3—OIL DISTRIBUTION BOX CASING

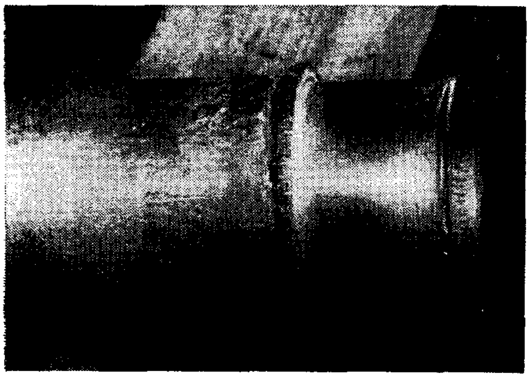

FIG. 4—AFTER SECTION OF FAILED OPERATING ROD

thought at this stage that these spares would have to be fitted. Unfortunately a spare oil distribution box was not available so it was necessary for the old box to be reclaimed by remetalling and machining the bearings.

The Hong Kong and Whampoa Dock Company had by then been called in for assistance, so both halves of the oil distribution box were removed from the C-P space to the dockyard for remetalling and machining of the bearings. This necessitated partial removal of the deck hatch coaming, the box being approximately 3½ feet long and 2½ feet square and weighing a total of 1½ tons. While this was being done the port thrust block cover was removed for examination of the thrust collar and pads but only 0·002 in. additional clearance was found above the last readings taken.

After thorough cleaning, heat was applied to the sliding ring and, as anticipated, the whitemetal bond melted and the ring than moved easily along its full operating distance along the shaft. The whitemetal was cleaned off and the shaft and ring oiled, allowing free movement.

The defect was then apparently in the valve rod or servo unit in the hub, possibly the valve pin having become disconnected at the bayonet joint, necessitating docking. The Cosmopolitan Dock at Kowloon was the only dock available and this for only five days, including docking and undocking. Unfortunately, no workshop facilities existed there and those requirements had to be dealt with at the dockyard two miles across the town.

After docking down, the port propeller blade position was again checked in the full ahead position. Removal of the hub cap was a comparatively simple operation but three ¾-inch mild steel cheese-headed screws secured the valve liner in the hub and these, having been peened over, required considerable effort to be removed. Two were unscrewed by welding a nut to the head and applying a box spanner. This itself was no easy task as they were approximately six inches inside the six-inch bore of the hub. The third screw defied these efforts, and had to be drilled out. Removal of these screws delayed the repair by twelve hours.

As soon as it was freed, the valve liner and pin in the hob were withdrawn, together with the valve rod. It was then found that the latter had fractured on the weld of a joining coupling, approximately ten feet from the forward end (FIG. 5). The forward face of the withdrawn valve rod was found hammered and belled where it had been bearing against the remainder of the rod in the

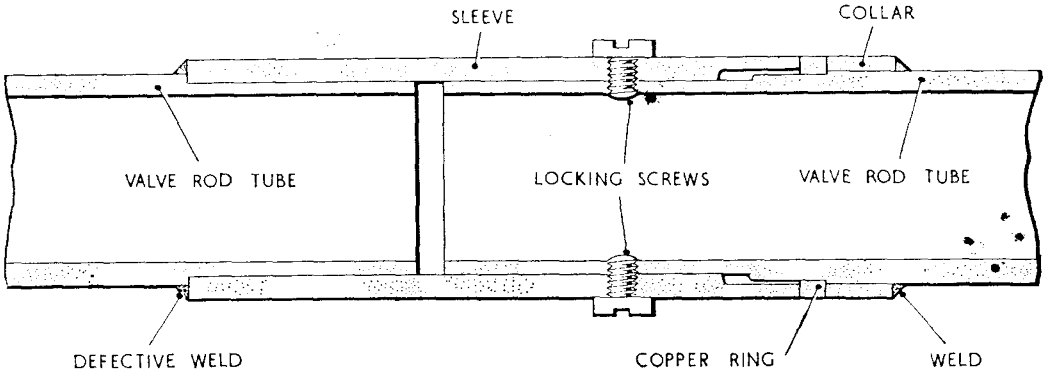

FIG. 5—VALVE ROD COUPLING

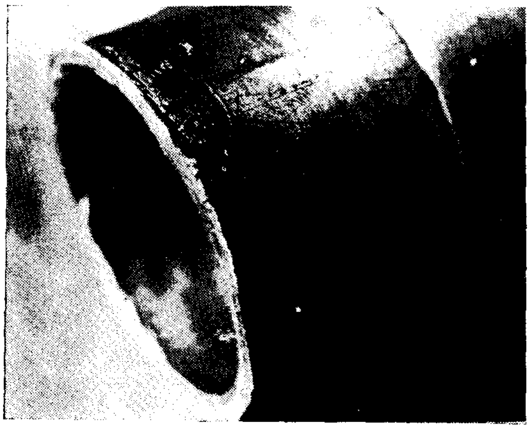

FIG. 6—SLEEVE OF FAILED OPERATING ROD JOINT

propeller shaft (FIG. 5).

Conclusion

The cause of the defect was now apparent and due to the failure of the after welded joint on the valve rod coupling. This permitted the high-pressure oil in the valve rod to pass directly into the low-pressure area in the propeller shaft, so releasing the oil pressure on the hub servo-motor piston. The speed of the ship at the time overcame the spring pressure in the hub, causing the blades to move astern, and this action withdrew the after section of the valve rod from the sleeve. After speed was reduced the hub unit springs moved the blades, piston and valve rod forward, but the latter failed to re-engage in the sleeve. The sliding ring was forced forward by the operating key, fouled the casing and bowed the key, causing the damage in the oil distribution box as described above.

Final Repair

The next problem to arise was how to remove the remainder of the valve rod, some 60 feet inside the propeller shaft. First thoughts were to break the Admiralty coupling just aft of the oil distribution box, withdraw the propeller shaft sufficiently aft to enable the broken valve rod to be grasped, slide it aft and eventually push it through the shaft with bamboo canes or searchers. This was decided against. A better suggestion was to remove a section of the intermediate propeller shaft between the thrust block and the forward end of the oil distribution box shaft. This only entailed moving the propeller shaft aft a couple of inches to free the spigots on the coupling, and would leave the forward valve rod, pin and liner free to be withdrawn forward. This was done, but it was found necessary to jack the propeller hub before the shaft could be moved at all. On drawing out the remaining valve rod it was seen that the after end of the coupling, where it was welded, was also hammered. Examination of the weld showed poor penetration on the vertical face, and it was surprising that the C-P gear had operated so long before failing.

The whole valve rod was unscrewed into sections and taken to Whampoa Dockyard for repair and X-ray of all welds. The damaged section of the rod and coupling were faired and the valve rod sections immediately forward and aft of the failure checked for alignment. This was satisfactory.

While the valve rod was away in the dockyard, opportunity was taken to flush the hub and servo unit with PX. 4 oil and the bore of the propeller shaft with OMD. 112, the oil normally used in the system. While flushing the hub, it was seen that oil leaked from one propeller blade seal and, as time permitted, awaiting the return of the valve rod and oil distribution box, the seal was renewed. The main C-P oil tank was also emptied, cleaned and refilled with OMD. 112.

When the valve rod was returned to the dock, it was reassembled and oil pressure tested. The only pump available was rather antiquated, at least 40 to 50 years old, and looked as if it had been salvaged from a pirate Chinese Junk. The patience and stoicism of the Chinese coolies then came to the fore. By pumping steadily for a half-an-hour or more, pressure was eventually raised and the whole valve rod tested internally to 500 lb/sq in.

The forward liner was replaced and re-secured into the propeller shaft, and the valve rod and forward valve pin re-inserted into the shaft through the hub. A misalignment of the new welding on the coupling of approximately 150 degrees gave rise to some concern. The dock owners were eager to get the ship out for them to continue normal merchant ship dockings, and the time allowed had already been extended by 24 hours. Instead of breaking and re-welding the coupling in its proper position, it was decided to make the necessary adjustments on the after valve pin ball connection, so ensuring the slot in the forward valve pin lining up with the slot in the oil distribution box shaft, and also allowing the bayonet catch connection on the after valve pin a full 90-degree turn for locking. The locking ring nut on this ball connection was tightened but new holes had to be drilled and tapped for insertion of the locking screws. After alignment had been ensured, the valve rod was replaced forward by insertion of the operating key, the after valve liner was replaced and secured and the hub cap fitted. The intermediate shaft was lowered into position and the couplings remade.

By this time the oil distribution box had been returned from the dockyard. The forward and after casing journals had been machined to give clearances of 0·010 in. as also were the location bearing faces. The top and bottom halves of the box were then bedded on to the shaft separately. Difficulty was experienced when the two halves were bolted together. Slight distortion of the box while remetalling caused the horns of the after end of the casing to bear on the shaft, and these necessitated scraping to give clearance. The box was finally rejointed and the bolts hardened up, and when tried on the shaft it swung freely by hand.

The suction and discharge pipes, shaft-driven lub. oil pump and torque arm, which had been straightened, were secured to the bottom-half casing. The control and indicator gear was replaced on top of the oil distribution box, the operating yoke with front and back covers were bolted into position, and the motor-driven pump was run to fill the system with oil. The gravity tank on the boat deck was filled to operating level.

The propeller blade pitch was worked throughout its range to clear all accumulated air pockets in the propeller hub. It was then operated first by local control hand lever on the oil distribution box and then by ECR primary control, and the blade pitch marked on the propeller hub was checked with the master indicator on the oil distribution box. The engine room bloctube secondary control was worked and, finally, control lever markings in the ECR were checked with the master indicator. These were in accord. Having found the blades on the propeller hub worked satisfactorily, the ship undocked and returned to H.M.S. *Tamar*.

Before carrying out basin trials, the operating gear and propeller pitch were checked by divers. One engine was then connected to the shaft which was turned at 125 r.p.m. for two hours with blades set at zero pitch, checking that no overheating occurred on the oil distribution box, then for a further two hours with 5 degrees ahead pitch set. On completion, divers were again sent down to check blade pitch with master indicator and ECR controls at various positions, and these were found satisfactory.

Sea trials were carried out the following day, first with the shaft-driven oil pump connected, and the controllable pitch worked satisfactorily. As the hydraulic knock still persisted the pump was disconnected after an hours' running, and further manœuvring trials were carried out using the electric pump to supply oil pressure at 320 lb/sq in. The temperature of the oil distribution box casing at the bearings steadied at 100 degrees F which was considered as a maximum of 140 degrees F at the bearing. As all proved well, the ship returned to harbour and sailed for Singapore the following day. Once clear of Hong Kong, design pitch was set and no further trouble arose, apart from occasional momentary fluctuations of 2 to 3 degrees pitch due to air still being present in the oil system. As the ship proceeded south to warmer climes, the oil distribution box temperature rose and steadied at 130 degrees F. This was comparable with the temperature of 127 degrees F on the starboard oil distribution box.

Finally, after arrival at Singapore, the oil in the system was changed, a new shaft pump fitted and by pressure testing the pump suction line *in situ*, two small leaks were found, made good, so eliminating the hydraulic 'knock'.

In conclusion, it must be said that the controllable-pitch propellers have operated completely satisfactorily since the ship was first commissioned, six years earlier, changing oil seals being the only major work carried out at refits. They provide a wide range of manœuvrability with shaft speeds not falling below 123 r.p.m., so maintaining a running speed of 550 r.p.m. on the ASR1 engines.

The machining and workmanship of the equipment was excellent and, apart from the bad weld which was probably carried out at the shipbuilder's yard, very little wear was apparent on any of the equipment.

It was unfortunate that the maker's representative was not available at the time of the repair, no doubt he could have saved us a lot of time. As it was, there was nobody, either on board or ashore, with any experience of the internal construction of this equipment.

The Hong Kong and Whampoa Dock Company was of great assistance in effecting the repair, their Chinese labourers being hardworking and willing, and the remetalling and machining of the oil distribution box bearings proved their skilled capabilities.

The ship was very fortunate in having the Fleet Maintenance Unit of H.M.S. *Triumph* available for assistance in stripping down the oil distribution box, and thanks must be given to them and to the Base Engineering Staff of the Commodore, Hong Kong, who, although lacking the labour, assisted at every opportunity. The ship's C.E.R.A. and the outside machinery E.R.A. were keen and enthusiastic and worked 24 hours about, liaising and checking the Chinese labour; not an easy task with the language barrier to overcome, but they did add a few useful words to their vocabulary for detailing young M(E)s in their duties. The defect as a whole provided many interesting problems, and useful experience and information on controllable-pitch propellers was gained by a lot of personnel.

With regard to the controllable-pitch propellers themselves, it is the Author's opinion that they provide a very favourable answer to manœuvrability in the lower speed range of Diesel propelled ships.